A Proposal for a Radiation Protection Scale to better communicate with the Public

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INTRODUCTION

Many scientists in the field of radiation protection and utilization of ionizing radiation wonder why it is so difficult to make the public understand what radiation protection is and what its goals are, why in some cases actions are taken to reduce exposures and in other cases not, and why there are "tolerable" levels of radiation exposure while in other cases a reduction of exposure levels is considered vital to protect the public or individuals. For the public, it seems, radiation is just bad at any level and everything has to be done to eliminate any radiation exposure at all.

Furthermore, we scientists wonder why it is so easy for the mass media to provoke a general feeling of anxiousness in the public anytime an exposure involving ionizing radiation is discussed in the media. No matter how small the actual or hypothetical exposure level is, a broad coverage is ensured.

It is also astonishing how it is possible to have also minor incidents with very little or no exposure on the front pages of the newspapers while much larger exposures by other carcinogenic substances usually never make front pages, often being considered not worthy of reporting at all.

In order to improve this understanding and thereby the communication with the public, a radiation protection scale is proposed by which exposures by ionizing radiation should become more transparent and easier perceivable by the public. A similar proposal was already put forward recently in the German-Swiss radiation protection journal in German (1). The positive resonance encourages the authors to present the proposal to a larger scientific community.

PROBLEM IDENTIFICATION

In the past a rather positive attitude towards ionizing radiation has been replaced by a critical and later by a negative attitude which tends to consider any radiation as negative. In this attitude which is more and more found both in the general public and the media, no differentiation between high and low doses is made. Any, however miniscule, amount of radiation exposure is considered detrimental.

This attitude, in combination with terms used in radiation protection which are not easily understandable by the public, often confusing and sometimes misleading, lead to a mistrust of the public in radiation protection principles and the scientists and governmental officials advocating it. A major problem in that context are the various units used in radiation protection which tend to confuse the public. Once it is Sieverts or microSieverts, than it's Gray or even more confusing "Becquerel". The lay public often cannot even distinguish between activity and dose or between dose and dose rate.

Another problem is the difficulty of the public to differentiate between low, medium and high doses and their possible implications. Particularly confusing are the different dimensions. While terms such as "milli-" or "kilo-" usually quantitatively assessable to the general public are, as they are used in everyday life (millimeters, kilogramm), terms as "Mega" or "Giga", not to mention "Tera", are not comprehendible for the overwhelming majority. They are just big or very big. A differentiation by the public is not possible, a fact that almost every scientist has already encountered when reading a newspaper with completely wrong units.

Even more problematic in that respect is the fact that usually the public and the media are not able to distinguish between units and subunits, in particular when they are abbreviated. Terms as Sv, mSv or µSv, all sound the same. The difference is hardly comprehendible to the layman. For that reason knowledgeable journalists do not use abbreviations, but write out "milli-Sievert" or "mikro-Sievert. But more often the opposite happens, in the papers a µ is changed to m to yield e.g. "mSv" instead of "µSv, or a m to M giving "MBq" instead of "mBq". For the public this may be of little relevance as its ability to estimate the meaning of a given dose is low, for the expert it is annoying because he does not get the information he would like to get from a given article in the media. For a reasonable understanding of a specific situation or occurrence by those members of the public which have a higher background in radiation protection and therefore may be opinion leaders this is detrimental.

To explain the risk factors associated with a certain exposure level is very tedious and readily requires longer explanations, especially when low doses are involved. Even than it leaves the layman with a strange feeling that he was not told the whole truth or that there is still a risk he was not told about. This is particularly true in an accident situation where there is no time for lengthy discussions and explanations and usually due to stress the public is not willing to accept scientific explanations by the experts.

Therefore, a simple, for the general citizen easily understandable scale for radiation exposure of human beings is required to assist in making radiation exposure values and their consequences to health more easily understandable for the general public and the media.

WHAT IS REQUIRED

In the past several scales were introduced in different scientific fields to assist the communication among scientists and between the experts and the public. Probably the best known among these is the RICHTER-scale describing the size of earthquakes. Although most people do not correctly understand the dimension of the numbers since most people do not understand a logarithmic scale where the exponents are used as numbers, they do understand the quality of the number and are able to distinguish between the different numbers given to characterize the size of an earthquake. Moreover, the same scale is also used by seismologists to define the level of an earthquake in a scientifically acceptable term.

Another example is the INES-scale (2). Although the classification according to this scale is not as directly related to a measurable quantity as the RICHTER-scale, the scale has proven to greatly assist in the communication among scientists and engineers, but moreover between scientists and the public or the media, respectively. Especially the later feature was a particular benefit of the scale. Before the introduction of the scale every incident or accident at a nuclear facility was reported as a "catastrophe" by the media, after the introduction of the scale the media coverage became much more adequate to the actual scope of the incident.

The most important feature about the INES-scale was the fact that the index of the incident could be given to the media together with the first press release or shortly after. This is of particular importance with incidences of minor concern or little impact where typically a later press information is not carried by the media anymore. This quick coverage together with a classification of the incident is vital in present-day communications where rarely a second statement will be brought by the media if it is not a "big event". In many cases thus, it may have assisted in limiting the interest of the media to a level adequate to the scale of the incident and thus preventing extensive coverage of an incident that was of little relevance.

After the Chernobyl accident classifications for exposure levels were introduced in some countries to assist in communicating with the public. In the GIS-countries a classification in ground deposition of ^{137}Cs (3) was introduced to characterize the dose to be received as a consequence of the fallout and to take appropriate countermeasures accordingly. Although some of the consequences with regard to long-term forecasts and the adopted measures may seem problematic, the scale proved to be a valid tool in communicating with the public. In Austria a scale with 4 levels was introduced for an improved handling of any future accidents. The scale was set up to assist in classifying an accident and its consequences and to make the public understand why and to what extent countermeasures are taken and why in other cases no measures are required. The scale is a quasi-logarithmic scale in that level I refers to a dose of 0.5 - 2.5 mSv, II for 2.5 - 25 mSv, III for 25 - 250 mSv and IV for doses > 250 mSv. Thus the scale is grouped according to decades of dose values and for each decade certain countermeasures are recommended to be considered. In the level 0 (dose < 0.5 mSv) no measures for a dose reduction are advised. In emergency exercises performed up to now the scale proved to be a very useful tool to communicate between radiation protection experts and decision makers as well as the emergency units.

In order to facilitate the comprehension by less knowledgeable persons, a radiation scale is required which is comparable to these other scales where events of a wide range from practically no consequences via observable effects to severe consequences are given in an understandable "risk-scale".

THE RADIATION SCALE

The proposed radiation protection scale should cover the whole range of possible exposures from very minute levels to high, detrimental values. A scale which may describe the effects or possible risk potentials of dose values over many decades in a simple manner, is, in a most sensible way, a logarithmic scale. Only by a logarithmic scale the wide range of exposure levels from the extremely low additional exposure levels of releases from normal operation of nuclear installations or ionizing sources for civil uses on to intermediate levels of natural radiation or medical exposures to high exposure levels as caused by accidents or war-related impacts.

To cover this range, a scale is proposed in which, similar to the RICHTER-scale for earthquakes, the exponent of the effective equivalent dose in micro-Sievert is used as a measure for the exposure level. To enable a comparison of effects, doses are used as parameters in the scale, not dose rates or other parameters as activity or contamination. The use of only a single parameter should also facilitate a comparison of exposures by different sources and practices. The effective dose is considered as most appropriate for this purpose though an

extended definition to the effective dose in the high dose region may be necessary.
In this way the scale is defined by:

A level **n** on the radiation scale is attributed to the dose of a given practice or exposure situation or any other type of exposure to ionizing radiation where

$$\mathbf{n} = \log H_{eff}$$

where H_{eff} ..... effective dose [µSv]

The levels and the attributable dose ranges typical for such a radiation scale as well as characteristic exposure sources for the various level ranges are given in Table 1.

Table 1 Radiation scale for communication with the public

Level n	Dose range (effective dose) H_{eff}	typical exposure	observable effects
< 0	0 - 1 µSv	Range of environmental and public exposure caused by human activities	no observable effects
0 - 1	1 - 10 µSv	Range of environmental and public exposure caused by human activities	- " -
1 - 2	10 - 100 µSv		- " -
2 - 3	0,1 - 1 mSv	Range of medical examinations	- " -
3 - 4	1 - 10 mSv	Range of environmental and public exposure caused by natural radiation, medical examinations	
4 - 5	10 - 100 mSv	Range of excessive exposure caused by natural radiation	effects only statistically detectable in very large population groups
5 - 6	100 - 1000 mSv		statistically detectable effects in very large population groups
> 6	> 1000 mSv	Range of lethal effects	Acute effects, Lethal effects

In this scale exposure levels of 0 to 1 mSv would be characterized by numbers of less than 3. Exposure levels of 1 to 50 mSv, typical for radiation workers in normal facility operation, would range from levels 3 to 4.7. Excessive exposures above permissible levels would be attributed to levels above 4.7.

Acute effects according to this scale would be attributable to a level > 5.7. Lethal effects would start at levels above 6. LED_{50} would be equivalent to 6.5. Above 7 absolute lethal levels are reached.

Exposures due to natural radiation levels would be characterized by a number between 3 and 4. Typical values for natural exposure levels would be around 3.5. The small variation of between 3.2 to 3.7 for most natural exposure levels might well demonstrate to the lay public the little relevance of typically observed variations in natural radiation exposure levels.

Typical limits used in radiation protection would be:

2.5 for 300 µSv,
3 for 1 mSv
3.7 for 5 mSv and
4.3 for 20 mSv

AN ALTERNATIVE VARIANT

An alternative approach to the above scale would be a more simplified variant in which only groups of dose ranges are defined. In such a scale the exposure would be characterized not by a decimal number, but by an integer number of 0 to 7. Each integer number would be characteristic for an exposure range of one decade starting with 1 µSv and ending above a dose level of > 1 Sv (group 7).

The definition of each level would be according to the following formula:

> The dose of a given practice or operation is attributed to a level **n** on the radiation scale where
>
> the lower limit of the level is defined by 10^{n-1} µSv and
> the upper limit by 10^{n} µSv

This scale is displayed in Table 2. Although it looks very similar to the version of Table 1, the main difference is that it does not permit to relate a given exposure value to a precise number. Rather, the scale is grouped in scale levels by which a whole range of exposure values are attributed to one scale level.

Table 2 Simplified radiation scale for communication with the public

Scale level n	Dose range (effective dose) H_{eff}	typical sources of exposure	observable effects
0	0 - 1 µSv	exposure of the public caused by human activities, additional exposure by nuclear facilities in normal operation	no observable effects
1	1 - 10 µSv	exposure of specific groups caused by human activities	- " -
2	10 - 100 µSv	operational exposure limits of releases of nuclear facilities to the average population	- " -
3	0,1 - 1 mSv	ingestion exposure by natural radionuclides	- " -
4	1 - 10 mSv	exposure of the public caused by natural radiation	
5	10 - 100 mSv	range of excessive exposure caused by natural radiation	effects statistically detectable only in very large population groups
6	100 - 1000 mSv	accidental exposures, medical therapy	statistically detectable effects in very large population groups
7	> 1000 mSv	severe accidents	Acute effects, Lethal effects

COMPARISON OF THE TWO SCALES

The logarithmic structure of both scales results in an easily understandable set of numbers indicating the hazard of a given exposure. Each type of scale ranges from 0 to 7 where the levels 0 - 3 of the scale describe the dose range of miniscule to low dose values below natural radiation exposure levels, level 4 the dose range of 1 - 10 mSv, i.e. the dose range of the natural radiation exposure, while level 6 and 7 define the dose range 0.1 to 1 Sv and above 1 Sv in where protective measures to reduce the dose are very important or absolutely required to avoid significant effects to the concerned individuals.

Both scales are principally not limited with regard to greater values than 7. As the press would say, "the on the upper-side unlimited scale" like the description which is currently used by the media for the RICHTER-scale. This would principally permit to also use a scale level beyond 7, e.g. 8 or 9, but since the scale is related to the exposure of human beings, this would cover just the range of acute lethal effects where a differentiation might not be of much benefit.

The basic difference in the scale variants is the fact that one scale permits a differentiated description of an exposure by a decimal number very similar to the approach of the RICHTER-scale while the other gives only a rough categorization. By that an exact description of an exposure in the terminology of the scale is possible without loosing the benefits of expressing doses in small numbers more comprehensible to the public. This would be comparable to the RICHTER-scale where also a differentiation of an earth-quake of size 5.7 to one of size 5.9 is possible.

The advantage of the second variant of the scale is that exposure levels are grouped in the scale in steps characterized by a digital number. This much simpler approach may be advantageous in communicating with the public in that exposures of similar but not exactly equal levels are only related to a single level on the scale. This may be easier to understand and also avoids unnecessary discussions on whether an exposure of 2.9 is more detrimental than an exposure of 2.7. This variant is more similar to the INES-scale where also only a grouping of events is performed. However, with abnormal events in NPPs a more precise characterization in decimal numbers does not make sense due the arbitrary approach in attributing numbers to the hazard of an event. Here a more precise categorization would be principally feasible.

We personally think that the second version of the scale may be preferable over the first. It seems sufficient for the purpose it should achieve. It is simple and easy to understand by the public and the media. And it avoids discussions on whether there is a difference in hazard between two close, but different decimal numbers. However, we believe that this is an issue which should be discussed by the scientific community.

DEFINITION OF DOSE

In order to compare different exposures, the dose is defined in the following way:

- dose values: only effective dose, no organ doses
- individual dose values, no collective doses
- exposure period: one year (or less)

Only effective dose values should be used for purpose of comparison. This applies also for very inhomogeneous exposures such as thyroid doses or small-area x-ray exposures. Organ dose have to be avoided by all means in order not to confuse. It is understood that according to ICRP-recommendations, at high dose values absorbed doses should be used. For the purpose of this scale, however, the effective dose should be used in order not to confuse further the public with another term.

The same applies to the collective dose. Although some exposures may be better described by a collective dose than by the individual dose, the scale is based on individual doses and the use of collective doses should be avoided in order not to jeopardize the basis of the scale.

Since the radiation scale is segmented according to doses values, a definition of the period over which the integral of the exposure is to be extended, is required. To be consistent with most exposure concepts a duration of one year seems to be most appropriate for this purpose. Annual exposures values are usually given for the exposure by natural radiation, for releases from nuclear facilities and for exposure of radiation workers. Therefore, it is believed that the dose received within one year is the appropriate parameter to be used for the definition.

Exposures which occur in shorter periods of time should be used in the scale in the same way as one-year exposure values. Even very short-term exposures like x-rays may be described by a scale level. If a short-term exposure is more than once per year, the sum over the average number of exposures should be applied. Thereby, also medical diagnostic doses could be expressed in the scale if converted to effective doses. This could assist the communication between patient and doctor on the issue of the exposure associated with a required x-ray exam.

The disadvantage of using annual exposure values is that it is not possible to properly express the long-term, continuous exposure such as natural radiation and compare it to a single, one-year exposure such as a medical exposure. To demonstrate the difference between the dose of a single annual exposure or an accidental exposure which typically occurs only once in lifetime, to an exposure which extends for a longer period such as natural radiation which lasts over the whole live-span, in a comprehensive way to the public, therefore, is virtually impossible. It is believed, however, that this disadvantage is not so great to justify other, longer periods over which the dose should be integrated.

The scale permits further a description of risks associated with each group of radiation exposure. This is shown in Table 3. It might be additionally very helpful in communicating with the public in that it demonstrates the rather minimal risk at lower levels of exposure, a fact which is not very well known by the man on the street. From the experience of the authors people are usually quite surprised when they learn that a dose of 10 mSv involves a long-term malignancy risk of about or less than 0.05 %.

Table 3 Associated risk factors (assuming a linear dose-risk relation)

Scale level n	Dose range (effective dose) H_{eff}	risk factors for long-term malignant effects
0	0 - 1 µSv	~ 0
1	1 - 10 µSv	~ 0
2	10 - 100 µSv	< 0.0005 %
3	0,1 - 1 mSv	< 0.005 %
4	1 - 10 mSv	< 0.05 %
5	10 - 100 mSv	0.05 - 0.5 %
6	100 - 1000 mSv	0.5 - 5 % *
7	> 1000 mSv	> 5 % *

* excluding deterministic effects

SUMMARY

A radiation scale is proposed which should lead to an easily understandable and comprehendible risk factor scale associated with the exposure by ionizing radiation. It should make various exposure levels more transparent in an environment where any level of radiation is considered by the public and the media as absolutely dangerous and no differentiation of doses is taken into account.

The proposed radiation protection scale is comparable to other scales known by the public and media like the RICHTER-scale or the INES-scale. Therefore, it should be easily acceptable by them. It is believed that the easiness of the scale and the small figures used as indicators for exposure levels may substantially improve the acceptance and encourage the application of the scale in the media. Also, the logarithmic nature assists in covering the wide range of possible exposures and still results in numbers easily comprehendible by media and public. Furthermore, by supplying an understandable "risk-scale", in the opinion of the authors the scale would facilitate the comprehension of the public why for a given dose no action to reduce it is considered and for another dose level dose reduction measures are recommended or considered absolutely required.

By avoiding different units most of which are not well understandable to the layman, confusion with regard to the possible detriment as observed after the Chernobyl accident or other events with accidental exposures may be avoided or substantially reduced.

The scale permits a correlation between scale levels and risk factors which is easily understood by the public. By that, the interested layman may estimate and understand the relative risk level of a certain exposure. By comparing it to other risks in society he may learn to see ionizing radiation in more relative terms then before.

From past experience the radiation scale will also improve the understanding and communication between radiation protection experts and governmental decision makers, politicians and the emergency teams involved in case of severe accidents. It could also significantly assist decision makers in explaining to the public why certain countermeasures are deployed only in a limited area of a country and not everywhere or to a specific group of the public and not everyone. This also should improve the credibility of the authorities in case of a severe accident.

REFERENCES

1. Mück K. Wie gefährlich sind die Millisieverts - Eine Strahlenexpositionsskala zur besseren Kommunikation mit der Bevölkerung. Strahlenschutzpraxis 5/1 (1999) 25-28 (in German)
2. The International Nuclear Event Scale for prompt communication of safety significance, OECD, Paris, IAEA, Vienna, (1992)
3. USSR State Comm. on the Utilization of Atomic Energy: The Accident at the Chernobyl NPP and its consequences. Post Accident Review Meeting on the Chernobyl Accident, IAEA, Vienna, Sept 1986; Safety Series N 75-INSAG-1 (1986)